

# **ENVIRONMENTAL OCEANOGRAPHY OF THE ARCTIC OCEAN AND ITS MARGINAL SEAS**

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## **OBJECTIVES:**

*Long-term:* To clarify the global role of the Arctic Ocean by investigating its essential biogeochemical characteristics. *Immediate:* 1) Continuation of Ice-Ocean Environmental Buoys (IOEBs) in the northern Canada Basin and middle Beaufort Sea to further understanding of the role of the permanently ice-covered Arctic in global biogeochemical cycles. (2) To quantify the export fluxes of essential biogeochemical elements and isotopes from the upper ocean to the ocean's interior in the hard-to-access Arctic Basin and its marginal seas including the Sea of Okhotsk. (3) Particularly, to understand the dichothermal-layer-controlled oceanography of the Sea of Okhotsk and to stage a high-grade international collaborative research with Japan, Russia and Korea.

## **APPROACH AND ACCOMPLISHMENTS DURING 1996**

### Arctic Basin Study; Deployment of IOEBs in the Arctic Sea

We have made significant progress in the ONR-supported IOEB (Ice-Ocean Environmental Buoy) experiment in the Eurasian Arctic Basin during the 1996-97. We have, for the first time, successfully collected export flux of carbon and other tracers from underneath the permanently ice-covered high Arctic throughout 12 months, in equal 17-day time segments, without hiatus, from April 1996 to April 1997. Information regarding the removal of material including organic and inorganic carbon from the Arctic Basin has been a secret tightly kept from oceanographers; therefore this breakthrough is extremely useful to further understand not only the high latitude environment but also the global role of the Arctic Ocean. Information on the seasonal and annual variability of the tracers and isotope fluxes will be useful for many ocean science disciplines.

Another effort concerning the IOEB experiment in 1996 was to gather, in precise time-series for multiple years, relevant, all-season environmental data in as coherent a manner as possible. Unlike data from other oceans, much of the critically important data for understanding the biogeochemical cycle in the Arctic Sea is extremely difficult to gather; we have, therefore, had to gather them ourselves. The resulting real-time Arctic-environmental data sets are now posted on the web and globally accessible. For example, the NSF-ONR-sponsored SHEBA program uses the data as one of its critical program elements. Useful physical oceanographic data and outstanding findings from the 1996 IOEB experiment include: (1) The analyses of continuously telemetered ADCP records reveal the detailed geographic distribution, structure, frequency and seasonality of baroclinic eddies in the Beaufort Sea. They are strongly related to the bathymetry off Point Barrow (Plueddemann *et al.*, in press). (2) The 1996 IOEB in the Beaufort Sea continuously encountered significant phytoplankton blooms which were indicated by telemetered fluorometer and transmissometer signals. Analysis indicates the forcing factor is the distance from

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the shelf-break under the permanent ice cover [Honjo *et al.* 1995 (in part); Honjo *et al.*, in preparation]. (3) We have established a working relationship with Dr. Comiso's group, Goddard Space Flight Center, NASA. We are also including Dr. Yang, WHOI, to compare various classes of satellite images and their numerical derivatives with our IOEB-based complete met-data to deepen the understanding of the air and ice processes. Our IOEB data observed during 1996 include a unique 36-thermistor telemetry-based, year-round ice-profile including skeletal ice zone variability.

#### Biogeochemical Significance of the Arctic and Its Marginal Seas

Logistic difficulties in mounting an ocean experiment in these seas are substantial. We solved a part of the problem by deploying automated time-series sediment traps with current meters and tiltmeter arrays. Following the successful first deployment at the approximate geographic center of the Sea of Okhotsk in 1993, we were able to deploy 2 moorings within the Sakhalin EEZ with the cooperation of SakhNIRO in 1995. However, our attempt in June 1996 to measure tracers and dissolved SiO<sub>2</sub> in the northern Primorye slopes in the northern Okhotsk Sea onboard U.S. Naval Research Vessel Vincent failed due to Russia's internal problems. (We surveyed Yellow Sea for a month while we were awaiting permission. This make-shift survey turned out to be one of the most detail oceanographic surveys ever done of almost the entire area of the Yellow Sea and the Korean Strait. We will report on it separately).

As we reported in two reviewed journals and two symposium volumes during 1996 and early 1997, we have reconfirmed our 1993 discovery: the Sea of Okhotsk may be one of the most efficient of the world's oceans, including the Equatorial Pacific and North Atlantic, for removing CO<sub>2</sub> from the upper oceans. The Sea of Okhotsk is the only ocean area which is comparably efficient to the divergent area of the Arabian Sea (Honjo, 1996, review paper). In the Sea of Okhotsk, organic carbon flux as large as 2 gC m<sup>-2</sup> yr<sup>-1</sup> was 3-fold greater than the inorganic carbon flux, indicating an extremely efficient ocean in exporting CO<sub>2</sub> to the ocean sink and dimersal resources near the bottom. The biogeochemical and the isotopic tracer data we have collected will be incorporated in a numerical model, expanding the model which was published in Yang and Honjo, 1996. Dr. Yang received separate funding from ONR in 1995 and 96 to further pursue OGCM using the data which has been generated by this program.

Fascinatingly, it appears that the Okhotsk biological pump is linked with a unique hydrography: the sub-zero dichothermal layer which covers the major part of this ocean. (Honjo *et al.*, 1997, in press). Together with a Russian scientists from SakhNIRO, we have reconfirmed the double-bloom in the Sea of Okhotsk which was originally found in 1993 with ONR support. A new, more detailed paper discussing the oceanographic role of the dichothermal layer is being prepared for publication (Honjo, Yang and Kantakov, in preparation). The Yang/Honjo model (1996) captured the main features of the Sea of Okhotsk, the dichothermal layer and its 5-year periodicity.

#### **LITERATURE REFERENCES**

Honjo, S., T. Takizawa, R. Krishfield, J. Kemp, and K. Hatakeyama, 1995, Drifting Buoys Make Discoveries About Interactive Processes in the Arctic Ocean, EOS, **76**: 209, 215, 219.  
Honjo, S., 1996. Fluxes of Particles to the Interior of the Open Oceans, In: Particle Flux in the Ocean, Ittekkot, V., Schäfer, P., Honjo, S. and Depetris, P. J., eds., Scope Volume 57, John Wiley & Sons, New York, 372 pp., 91-154.

Yang, J. and Honjo, S., 1996. Modeling the dichothermal layer of the Sea of Okhotsk. *Journal of Geophysical Research*, **101** (C7): 16421-16433.

Honjo, S., 1997. The Northwestern Pacific Ocean, A Crucial Ocean Region to Understand Global Change: Rationale for New International Collaborative Investigations. In: Biogeochemical Processes in the North Pacific: Proceedings of the International Marine Science Symposium held on 12-14 November 1996 at Mutsu, Aomori, Japan. Japan Marine Science Foundation, Tokyo, pp. 233-248.

Honjo, S., Honda, M., Manganini, S. J. and Ishii, H., 1997, *in press*. Biogeochemical Cycles in the Sea of Okhotsk, a Temporarily Ice-Bound Large Marginal Sea, *Deep-Sea Research*.

Plueddemann, A., Krishfield, R., Takizawa, T., Hatakeyama, K. and Honjo, S. et al., *in press*, Beaufort eddy-field, observation by IOEBs during 1993-1996. *Geophysical Letters*.

Honjo, S., Krishfield, R., Manganini, S. and Takizawa, K. (in preparation) Onset of seasonal bloom under the permanently ice-covered Eurasian Arctic Ocean. to be submitted to *Deep-Sea Research*.

Honjo, S., Yang, J. and Kantakov, G., *in preparation* New aspects of the high latitude dichothermal layer. to be submitted to *Journal of Geophysical Research*.

## APPLICATIONS

1. Because of its unique refractivity, the sub-zero dichothermal layer, which has been described in detail by this program, will be significant for Naval acoustic applications.
2. The IOEB technology with its multi-sensor application, high communication capability, longevity and durability in ice-fields is applicable to many types of ocean science, naval research and nuclear pollution research.

## EDUCATION

Susan Alderman (f), Masters Degree in Oceanography, 1996 MIT/WHOI Joint Education Program. Thesis Title: "Seasonal Transition of Species Composition and Isotope Variability of Planktonic Foraminifera in the Sea of Okhotsk."

## PUBLICATIONS

Francois, R., Honjo, S., Manganini, S. and Ravizza, G., 1995. Biogenic barium fluxes to the deep-sea: Implications for paleoproductivity reconstruction, *Biogeochemical Cycles*, **9**(2): 289-303.

Honjo, S., Dymond, J., Collier, R., and Manganini, S. J., 1995. Export Production of Particles to the Interior of Equatorial Pacific Ocean During 1992 EqPac Experiment, *Deep-Sea Research*. **42** (2-3): 831-870. (Mentioned for comparative study.)

Honjo, S., T. Takizawa, R. Krishfield, J. Kemp, and K. Hatakeyama, 1995, Drifting Buoys Make Discoveries About Interactive Processes in the Arctic Ocean, *EOS*, **76** (21) 209, 215 & 219.

Honjo, S., 1996. Fluxes of Particles to the Interior of the Open Oceans, In: Particle Flux in the Ocean, Ittekkot, V., Schäfer, P., Honjo, S. and Depetris, P. J., eds., Scope Volume 57, John Wiley & Sons, New York, 372 pp., 91-154.

Honjo, S., 1996. Toward predictable carbon cycle modeling in the Sea of Okhotsk, pp. 3-10. In: The Sea of Okhotsk, Honjo and Takizawa, eds., Science and Technology Agency, JAPAN, 264 pp. (not peer-reviewed)

Honjo, S. and Manganini, S., 1996. Formation of dichothermal layer and long-term carbon flux in the Sea of Okhotsk, pp. 25-31. In: The Sea of Okhotsk, Science and Technology Agency, JAPAN, 264 pp. (not peer-reviewed)

Yang, J. and Honjo, S., 1996. Modeling the near-freezing dichothermal layer in the Sea of Okhotsk and its interannual variations. *Journal of Geophysical Research*, 101 (C7): 16421-16433.

Honjo, S., 1997. The Northwestern Pacific Ocean, A Crucial Ocean Region to Understand Global Change: Rationale for New International Collaborative Investigations. In: Biogeochemical Processes in the North Pacific: Proceedings of the International Marine Science Symposium held on 12-14 November 1996 at Mutsu, Aomori, Japan. Japan Marine Science Foundation, Tokyo, pp. 233-248.

Honjo, S., Honda, M., Manganini, S. J. and Ishii, H., 1997 *in press*. Biogeochemical Cycles in the Sea of Okhotsk, a Temporarily Ice-Bound Large Marginal Sea, *Deep-Sea Research*.

Plueddemann, A., Krishfield, R., Takizawa, T., Hatakeyama, K. and Honjo, S., et al, *in press*, Beaufort eddy-field, observation by IOEBs during 1993-1996. *Geophysical Letters*.

Krishfield, R., Takizawa, T., Hatakeyama, K., and Honjo, S., 1995. IOEB Data File and Graphic Plots, 1992 to 1995. Woods Hole Oceanographic Institution Technical Report, WHOI-95-16, 185 pp.

Honjo, S. and Takizawa, T. (editors), 1996. The Sea of Okhotsk, Transactions from the Sea of Okhotsk. Tokyo. Science and Technology Agency, JAPAN, 264 pp.

Ittekkot, V., Schäfer, P., Honjo, S. and Depetris, P. J. (editors), 1996. Particle Flux in the Ocean, Scope Volume 57, John Wiley & Sons, New York, 372 pp.

Honjo, S., 1995. "The Oceanographic Significance of the Sea of Okhotsk." Invited keynote paper for the 10th Okhotsk Sea-Ice Conference, Mombetsu, Hokkaido, Japan (invited), January 10-14, 1995.

Honjo, S. 1996. "The Northwestern Pacific Ocean, A Crucial Ocean Region to Understand Global Change: Rationale for New International Collaborative Investigations." Invited keynote paper for The International Marine Science Symposium, Mutsu, Aomori, Japan (invited). November 12-14 1996.